NASA-CR-197138

Georgia Tech

NAGW-3181

Speckle Imaging of Young Planetary Systems

James W. Beletic, Georgia Tech Research Institute

Final Report — Summary of Work on GTRI Project #A-9288

The Georgia Tech Research Institute (GTRI) undertook a program to attempt to produce high resolution visible light images of young planetary systems. These protoplanetary systems are expected around young stars, such as T Tauri type stars. Although most flux is in the infrared, this program has been attempting to image candidate stars using speckle imaging at large telescopes in both the northern and southern hemispheres.

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The following GTRI personnel participated in this program:

- Dr. James W. Beletic
- Mr. Alan Gilbert
- Mr. C. Michael Adkins

For this effort, the GTRI research team has the following suite of unique equipment:

- A high speed, low noise CCD camera system that is presently the best in astronomy for high frame rate imaging. The 420 x 420 pixel, frame transfer CCD chip can be read out of its single port at 1 million pixels per second with a readout noise of 6–8 electrons (rms). The backside illuminated chip attains 80-90% quantum efficiency over the wavelength range of 430–800 nm and subarrays can be read to attain frame rates of 100 Hz and higher.
- A PAPA photon counting camera which is photon noise limited on medium to large telescopes for objects brighter than 19th magnitude. The primary drawback of this camera is its relatively poor quantum efficiency of 3–5% over the visible band.
- A complete system with optics box (for shuttering, atmospheric dispersion correction, filtering and magnification), fiber optic data link for telescope to control room, real-time image display, a high speed data recording system (4 Mbytes/sec) and computers with array processor for data processing. The complete camera systems are readily transported to remote sites for observing runs. The GTRI system has been on over a dozen observing runs on 3 continents with no significant loss of telescope time to camera system failure.
- Fully developed speckle imaging algorithms, using the community recognized most advanced approaches to image reconstruction; including constrained iterative deconvolution for the power spectrum and the bispectrum for recovery of object phase information.

During the contract period of 1 July 1993 through 30 June 1994, the GTRI personnel undertook the following activities:

1) Reduction of speckle data from other observing runs, including data from the Michigan-Dartmouth-MIT 2.4-m telescope on Kitt Peak, the Steward Observatory 90-inch telescope on Kitt Peak.

The results from processing of Northern hemisphere T Tauri stars has been negative, in that no planetary disks have been found with this technique. The data is either reconstucted into point sources or the objects are so faint (combined with poor seeing) to produce image reconstructions that exhibit a high level of noise.

2) Collection of data during two observing runs. The first was at the Carnegie Institution's 100-inch telescope in Las Campanas, Chile in April, 1994. The goal of this run was to collect data on southern hemisphere objects in order to produce high resolution visible images of young planetary systems. The second observing run was at the United Kingdom's 4.2-meter William Herschel Telescope on La Palma, Canary Islands in May, 1994. This observing was for collection of standard speckle imaging data and also to foster collection of adaptive optics images, which will soon be the best ground-based method for high resolution imaging. (More on adaptive optics below.) The data from both of these observing runs is still being processed and no conclusive results are yet available.

The GTRI speckle imaging group has a significant amount of experience in astronomical speckle imaging. We have the most advanced imaging systems in the world and we were part of the research team at Harvard that developed the first predictive models for the performance of speckle imaging. We have used the imaging sytems and reconstruction algorithms to take the highest resolution ground-based images of Mars, Pluto and binary star systems. However, there are very basic limitations to the performance of speckle imaging. The best approach for the future of ground-based imaging is adaptive optics, the technology of sensing and correcting for the atmospheric distortions before the light is incident upon a detector.

Our strategy for high resolution visible imaging of young planetary systems has branched into adaptive optics during the past year. We have established collaborations with the U. Arizona, the Carnegie Institution and the U. Durham (UK) in order to undertake joint observing runs that collect speckle data and adaptive optics data. The goal is to have collaborations in place so as to be able use the adaptive optics systems when they come on-line. There is always the option to combine speckle imaging with adaptive optics, but the best approach is to take a high Strehl adaptive optics image if possible.

During the coming year, we plan more observing runs at the United Kingdom's WHT 4.2-m telescope, both with straight speckle imaging and with the MARTINI adaptive optics system. We also plan to complete all of the data processing and produce a publication summarizing our work.

During the last year we did not produce any publications in refereed journals on this work.

September, 1994